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BIOLOGICAL SCIENCE

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BIOLOGICAL SCIENCE

AN ENQUIRY INTO LIFE

Biological Science Curriculum Study

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ART 1 UNITY

e earth is populated by millions of different types of living creatures. Each has its own way of ng, but all share *the only known kind* of structural and chemical organization that means *being* e. Whatever their dissimilarities, plants, animals, and other creatures solve their big problems – e of being alive – in much the same way. The study of these unifying features will be one theme art 1. We will also learn how biologists acquire knowledge of living creatures.

APTER 1 **Biology – What Is It About?** 1

Biology is the sum of man's knowledge about life – his own life and that of all other creatures. This knowledge consists not only of a collection of facts, but more importantly, of the way these facts are associated and interpreted in general theories. An example of a biological investigation is the theme of this chapter. The cause of mankind's most serious disease, malaria, is used as a case history in showing how man attempts to answer his biological questions.

PTER 2 **Life from Life** 19

Less than a century ago scientists debated furiously the question of whether life could arise spontaneously from nonliving substances. The far-reaching implications of this biological question are not necessarily the same for life today and life in its most distant past. But they *are* the same for all kinds of living things, as investigation of this biological problem in terms of life today has abundantly illustrated.

PTER 3 **Basic Structure** 38

Unifying theories relate isolated facts. Science is at its best when it seeks a new theory to organize an accumulation of poorly understood facts. One of the greatest unifying theories of biology is that all, or nearly all, forms of life have a common basic structure. That this is true is not at all obvious: a fish and a tree really do not seem to resemble one another. Yet both are alike in being composed of cells. Cells were first discovered almost 200 years before their nature was understood well enough to lead to the cell theory.

CHAPTER 4

Basic Functions

If nearly all forms of life have a common basic structure – cells – do they also mon functions? Does life as a fish have anything in common with life as a biological question is closely connected with the history of chemistry – esp the argument that life can be understood in terms of the same general laws th all matter.

CHAPTER 5

Living Chemistry

Even though all forms of life – all living organisms – exist in full conformity wi patterns that we recognize as the laws of chemistry and physics, the patterns volve *complex* chemistry and *complex* physics. Living organisms are composed that are common in the nonliving world, but these atoms are much more comp ganized than in nonliving matter. Only in living structures are atoms found organ large molecules of nucleic acids, proteins, carbohydrates, and fats. The cells of creatures are composed chiefly of these same classes of chemical substances.

CHAPTER 6

The Physiology of Cells

A living cell, with its huge number of complex substances, exhibits ceaseless ch activity. Substances are entering and leaving the cell at all times, as molecules are built up and broken down within the cell. Transfers of energy for all the cell's activi occurring constantly. These ceaseless processes of chemical and energy change a

CHAPTER 7

Reproduction – of Cells – of Individuals

The most basic characteristic of life is reproduction; that is, the production of ne tures and individuals similar to the existing structures and individuals. Repro occurs at different levels of organization. Parts of the cell, such as the chrom produce new chromosomes. Cells then produce new cells; and individuals, offsp themselves. In this chapter, reproduction by cells and by individuals is discussed of a fundamental feature – the replication and distribution of chromosomes in mit meiosis.

CHAPTER 8

The Hereditary Materials

The physical basis of genetic continuity can be traced from cell to nucleus to chrom In this chapter you will list the requirements for a hereditary material, then begin for molecules that fulfill these requirements. The observations and experiments t to the belief that DNA is the hereditary material are used as an inquiry into sc procedures. Finally, the manner in which the hereditary instructions of DNA relate specific proteins of the cell is described.

RT 2 DIVERSITY

ersity among the earth's microorganisms, plants, and animals is more obvious in many ways the fundamental unity in life. Historically, diversity emerged as modifications upon a common ern. Unity continues to be shown in the recognition that different organisms are similar chem-ly, have a common structural basis in cells, reproduce, evolve, respond to stimuli, and constitute s of an interrelated whole. Yet diversity in life is seen in the millions of different types of living nisms – the three principal groups being microorganisms, plants, and animals. This section of book will be concerned with the many variations upon the fundamental theme.

RT 2a MICROORGANISMS

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Several billion years ago the earth was vastly different from what it is today. The primeval seas may have become rich mixtures of organic molecules. Probably a chance combination of molecules produced a larger molecule (possibly similar to the DNA of today) that had a chemical structure giving it a pattern for exact duplication. Slowly, the duplicating molecules became parts of more complex systems, until they could be called "organisms." From these humble beginnings life spread over the earth and evolved into its innumerable species – each an experiment in living in a particular way. The viruses of today may represent a level of complexity similar to that of some of the earliest forms of life. They cannot live independently but require a living cell for their life and reproduction. This may be analogous to the requirements of the hypothetical first organisms for an environment rich in organic compounds.

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The bacteria, more complex than the viruses, are the simplest organisms that can be called cells. They also are the smallest organisms that can be studied with the compound microscope. Their activities are basically those of *every* living organism. Life in the simplest cells can be very complex – even to reproduction by sexual means.

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Because of their small size, bacteria were discovered only after the invention of the microscope. Their importance became rapidly recognized, for they are organisms that cause spoilage, decay, and disease, but that have many useful activities. The discovery that bacteria cause disease is one of the most interesting examples of the methods of science. Bacteria are beneficial in industry, food preparation, and vitamin production, mostly because of their ability to carry on fermentations that result in valuable byproducts.

PART 2b PLANTS

CHAPTER 12 **Molds, Yeasts, and Mushrooms**

Collectively known as fungi, the molds, yeasts, and mushrooms are more ... bacteria. They represent distinctive lines in the evolution of organisms that ... on photosynthesis. They, like the animals, are dependent ultimately upon the ... Together with the bacteria they are the chief decomposers—they break down ... of dead animals and plants and release substances that are used by the living ... decomposition activities, fungi may do great damage to timber, stored foods, ... products. In another role, as producers of plant diseases, they have affected the ... tion of the world's population.

CHAPTER 13 **The Trend Toward Complexity**

The most successful line of plant evolution gave rise to the green plants. ... simplest are the green algae. From their origin in the sea, green algae provided the ... of the green land plants. Although this happened long ago, the evolutionary step ... plainly seen by the study of present-day algae.

CHAPTER 14 **The Land Turns Green**

More than 400 million years ago, some species of green algae evolved into ... could live on land. Until then, the land had been barren and lifeless. Slowly the ... a mantle of green—the life-supporting green of photosynthetic organisms. Special ... tures and processes, primarily for obtaining water, carbon dioxide, and mineral ... pounds—and for preventing subsequent loss of water—became necessary for ... on land. The liverworts and mosses of today are reminders of some of the early ... ments in the evolution of green land plants.

CHAPTER 15 **Photosynthesis—The Link Between Two Worlds**

Life is the child of light. Green plants capture the energy of sunlight and use ... thesize energy-rich compounds. These compounds are the sole source of energy ... all other organisms. The essential substance in green plants that makes photosynthesis ... possible is chlorophyll, which in most land plants is concentrated in leaves. In the ... leaves, H_2O and CO_2 are used in the manufacture of sugars and amino acids.

CHAPTER 16 **Stems and Roots—A Study of Complementarity of Structure and Function**

Stems and roots support the leaves in elevated positions in which maximum light ... received. The water used in photosynthesis is absorbed by roots and transported ...

through the tissues of the roots and the stem. The rapid movement of materials and the support of leaves are aided by the complex conducting systems that have evolved in the vascular plants.

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Green plants are producers; animals are consumers. Given a proper temperature and the necessary inorganic substances, green plants can live wherever there is light. Animals can live only where there are green plants or products derived from green plants. This basic dependence defines the boundaries of the world of animals. The animal way of life—whether of a single-celled organism such as *Amoeba* or of large and complex animals—makes a series of demands on the world of life. These demands can be understood from the study of one kind of animal and its dependence upon other organisms and upon the nonliving environment.

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There are probably two million species of animals living today. Fundamentally, all live the same way, but in detail they vary tremendously. The many animal species can be classified into major groups known as phyla. Ten of these phyla include at least 98 percent of all known animals. The known history of animals begins more than a half billion years ago, when all their ancestors lived in water. Much later, some of the animals evolved modifications permitting them to colonize the land.

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In animals that have many cells, some degree of specialization, or division of labor, occurs among the cells. Some of the cells may be specialized in capturing food, others in digesting it, still others in coordinating these activities and additional ones. Digestion is carried out in a simple sac (in *Hydra*) or a complex sac (in planarians), a simple tube (in some worms) or a complex tube (in grasshoppers and many other animals, including man). This chapter is a study of one essential aspect of this division of labor—the enzyme-controlled breakdown of food substances.

CHAPTER 21

Transportation Within Multicellular Animals

Multicellular animals require a mechanism for transporting materials throughout the Sometimes simple diffusion will suffice, as in *Hydra*, but diffusion can supply the re ments of only very small bodies. Animals of larger size and complexity have tra systems. How these systems are constructed and how they function is the subject o chapter.

CHAPTER 22

Respiration in Multicellular Animals

In animal cells, carbon dioxide is a major product of energy-liberating reactions. O is often required in these reactions. Respiration involves the exchange of oxyge carbon dioxide by the animal with its environment, as well as energy-liberating rea within the cells.

CHAPTER 23

Excretion and Homeostasis in Multicellular Animals

Excretion is the removal from the body of chemical substances present in excess. In tion to water and carbon dioxide, major waste products in animals include one or nitrogen compounds such as urea. Respiratory processes eliminate carbon dioxide, nitrogen-containing wastes in larger animals usually are removed by specialized exc organs such as kidneys. Heat released in metabolism also poses a problem, and s homeostatic mechanisms may regulate body temperature, apart from the mechanism regulate body chemical makeup

CHAPTER 24

Coordination in Multicellular Animals

Multicellular animals, with their many types of specialized cells, have special me coordinating the activities of all the parts. Coordination is brought about in two g ways: control by nerves and control by chemical substances known as hormones. mation and "orders" are carried from one part of the body to another by both the and the hormones.

CHAPTER 25

Animal Support and Locomotion

One of the most obvious characteristics of the animal way of life is movement. S celled animals may move by cilia, flagella, or by a flowing motion of the cell itself. complex animals move by means of tentacles, wings, feet, fins, and sometimes ev cilia. In many instances the movement is dependent upon the contraction of muscle c contraction made possible by special chemical reactions and the energy of ATP. A the more complex animals, body movement usually involves supporting structure the body—a skeleton on the inside, as in man, or on the outside, as in the insects.

TER 6 **Reproduction in Animals** 472

Reproduction is a prime attribute of life. It may be asexual, as when a single-celled animal divides into two, or it may be sexual, involving the production and union of an egg and a sperm. Sexual reproduction – so widespread in the living world that we must assume it to be the most successful type so far evolved – provides for great variety in the hereditary makeup of organisms. The reproduction of most animals, including man, is sexual.

TER 7 **The Development of Animals** 493

In sexual reproduction, the union of a sperm and an egg produces a fertilized egg. The fertilized egg is only a single cell and, hence, is vastly different from the multicellular adult. The events that occur during the gradual growth and change from fertilized egg to adult are known as development. Basically, development consists of an increase in the number of cells, the differentiation of cells into different types, growth, and the organization of cells into the structures of the adult.

TER 8 **The Analysis of Development** 505

For centuries man has speculated on the underlying factors that control development. How can the fertilized egg, itself a single cell, develop into a complex adult with its many forms of cells, tissues, and organs? One hypothesis was that the adult body was preformed in miniature in the sperm or in the egg. When microscopes were available, it was possible to make the observation that disproved this hypothesis. Biologists of today believe that the complexity of the adult is a slow development from the simplicity of the embryo, and they are performing experiments to learn how this comes about.

RT 3 **CONTINUITY**

g organisms of today are the passing manifestations of a lineage of life that extends back- in time for several billion years. Individuals die, but life continues in their offspring. Two cts of the continuity of life by reproduction must be considered. First is the short-term con- y based on transmission of hereditary instructions from one generation to the next. Second e long-term continuity – evolution – based on mutation, recombination of alleles, and changes equency of alleles because of natural selection.

PTER 29 **Patterns of Heredity** 521

A fertilized egg is always of insignificant dimensions when compared with the adult it will form. Yet this single cell contains all the information necessary for its development into

a full-grown organism. Heredity is the process by which this information is
from one generation to another, in exact and predictable ways, as set forth
discovered by Gregor Mendel, and by others in the century since Mendel's

CHAPTER 30

The Chromosome Theory of Heredity

The exact and predictable nature of inheritance suggests that it has a physical
cell. During the first quarter of the twentieth century, biologists discovered
basis: the information of inheritance is carried by genes, which are parts of
The arrangement and distribution of chromosomes during the formation
sperms, and the particular combinations of chromosomes that occur at fertiliz
mine the pattern of heredity. As a part of this pattern, there is even a basis for
tion of genes located on the same chromosome. Specificity of hereditary
appears to be due to a specific sequence of nucleotides in the DNA of the

CHAPTER 31

Darwinian Evolution

More than a century ago, Charles Darwin announced his hypothesis of evolu
of the most profound intellectual insights of all time. He offered a rational explan
the innumerable different species that live on the earth, and for the changes that
them with the passage of time. The fossil evidence of life long ago, and the evid
rived from the study of life today, have substantiated the correctness of Darwin's
esis, which has become a major part of the theory of evolution.

CHAPTER 32

The Mechanisms of Evolution

In Darwin's time the available biological data were not sufficient to prove the co
of the hypothesis of evolution. More than half a century later, the careful stu
heritance did provide the necessary theoretical basis. We now understand the
hereditary differences among organisms. From among genetically different ind
those whose inherited characteristics best fit them to their environment are se
nature; that is, the "better" gene combinations survive in the succeeding ge
whereas the "inferior" gene combinations do not. Isolation—in terms of geogra
riers to mixing, and gradually emerging genetic barriers to interbreeding—helps
the separation of closely related populations into new species.

CHAPTER 33

The Evolution of Man

The biological processes that affect all other life affect mankind as well. Man
evolved—and has done so at a spectacular rate unequalled elsewhere in the wo
Within the last two million years he has reached the stage at which he could
"man" in the full sense of the term. Since then he has passed through a long cultu
hood, as he slowly learned to use tools and fire and to communicate with his fell

APTER 34

The Cultural Evol

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ART 4 INTERACT

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APTER 36

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PENDIX

APTER 37

A World

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APTER 34 **The Cultural Evolution of Man** 627

In the last 25,000 years man has changed little in his structure, but tremendously in his way of life. He has domesticated plants and animals and has solved, in increasingly better ways, a biological problem that he cannot escape—the need for food. He has built towns and cities and developed the science and technology that is the basis of civilization. His mind and hands have produced science, art, and literature. He has the information necessary to provide the individuals of his species with a secure and rewarding life.

ART 4 INTERACTION

l levels of biological organization there is unity, diversity, continuity, and interaction. We turn to the last of these. No individual is complete in itself. Its behavior, and life itself, is a consequence of interactions with other individuals of the same species, with the individuals of different species, and with the entirety of the living and nonliving environments.

APTER 35 **Animal Behavior** 645

Organisms are constantly active, responding to processes within themselves, to the presence of other organisms, and to the nonliving environment. Such activities and interdependence among organisms are particularly obvious in animals. Biologists analyze the entire pattern of animal activities in the study of animal behavior.

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All organisms are the products of their genetic makeup and their environments. Under the influence of the environment, evolution occurs, for the environment selects organisms genetically best suited to survive in certain habitats. In each habitat, green plants are the primary producers, and other forms of life are the consumers. The stockpile of materials in dead organisms is decomposed and returned to living circulation by bacteria, fungi, and other decomposers. All organisms on earth are part of a great cycle that ultimately depends on the energy of sunlight.

PENDIX 841

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Plants, animals, and microorganisms, together with the environments in which they live, make up interdependent units or ecosystems. An ecosystem may be in the open ocean or in the shallow sea along the shore. On land it may be in a forest, or on mountains, grasslands, tundra, or desert. Each of these, because of physical and biological factors, supports a different set of living things.

CHAPTER 38 **Mankind: a Population out of Balance**

Among the biological problems that man cannot escape is his own effect on
Primitive man generally lived in balance with nature. He was an integra
biological community. Civilized man, especially in recent centuries, has app
with an arrogance that could be his own undoing. He has destroyed vast area
soil by poor agricultural practices; he has devastated forests, only to find hi
diminishing and his soil supply eroding; he has fouled rivers and streams, th
their water unsuitable to his needs. But today he is beginning to behave a
a living creature who depends on other life for his existence.

CHAPTER 39 **A Perspective of Time and Life—Molecules to Man**

Man and all other living species are products of the past, associating in the pr
linked not only to the creatures around us but to those no longer living—a
before life began. In this final chapter the diversity of organisms, extinct
portrayed against the background of the evolution of the earth itself.

Acknowledgments to Scientific Societies and Individual Revie

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